summit of an isolated peak—is not the true temperature of the air column. In order to determine an exact reduction for an individual station it is only necessary to arrange each difference in pressure between the summit and base according to the mean temperature between base and summit at the same time. In this way a table has been formed for the reduction of observations at Mount Washington. (See Professional Paper No. VI, p. 8.) The error of the theoretical reductions at 0°, at 22.5 inches, is —0.36 inch, and at 22.0 inches it is —0.23 inch.

If all the high stations in the country were situated like Mount Washington, with a station at sea level, or near the base, it would be an easy matter to determine a table of reduction for each station. In the western portion of the country, however, the high stations are on an elevated plateau, and the above plan must be modified. We may say, in general, that any system which will enable us to draw isobars connecting the reduced values at elevated stations with those quite near sea level and west of the plateau region, may be considered fairly satisfactory as a first approximation. In the practical working out of this principle the plan adopted at Mount Washington was carried out. An approximate law of reduction on the east and west sides of the plateau region was

found, and when those were seen to be nearly the same they were united in a single formula which enabled the construction of the table here given. After applying this table to make actual reductions it was found that a few stations, owing to their greater or less isolation or to individual peculiarities, did not have perfectly satisfactory reductions. In those cases it was necessary to modify the temperature argument slightly to bring them in harmony with the rest. These stations at the present time are Baker City, Cheyenne, Denver, El Paso, Santa Fe, and Winnemucca.

It was found that in using the observed temperature for the reduction too much weight was given to existing conditions, as the atmosphere did not seem to respond immediately to temperature changes. By taking a mean of the observed temperature and that at the previous observation a fairly satisfactory result could be had, and this is the adopted method. It has been found that at times there are abnormal conditions of both temperature and pressure which throw out the reduction at a limited number of stations, but even in those cases the general reduction is satisfactory. Such conditions are more prevalent in Wyoming, Idaho, Montana, and in Canada to the north of the latter State.

THE TOTAL QUANTITY OF AQUEOUS VAPOR IN THE ATMOSPHERE.

By Prof. C. ABBE.

The diminution of aqueous vapor in the atmosphere with altitude above sea level was approximately determined by Hann in 1874 (see the collection of translations entitled "Short Memoirs on Meteorological Subjects," Annual Report, Smithsonian Institution, 1877, p. 376). Hann showed that all observations on mountains or in balloons, then available to him, agree in giving a simple law of diminution of vapor tension that is empirical, but not contrary to what we know of the laws of the diffusion of vapor. This law is

$$\frac{p}{p_0} = 10^{\frac{-h}{6517}}$$

where p and p_0 are the vapor tensions at top and bottom of an air column whose height in meters is h. The constant 6517 may vary with the temperature of the column, but observations were not available for determining this fact; Hann subsequently used 6500 as the constant instead of 6517, and this formula agrees within 1 per cent with the general average of all available European observations.

The total quantity of water present as vapor in a unit volume of air at any height in the atmosphere is given by introducing the above equation into the ordinary expression for the weight in kilograms of the vapor in a cubic meter of air, which therefore becomes

$$q = \frac{0.0010582}{1+at} p_0 \; 10^{\frac{-h}{6517}}$$

where a is the coefficient of expansion, and t the temperature of the air in centigrade degrees.

This value for q may be introduced into the differential equation for the quantity of vapor in a column of air reaching from sea level up to the altitude h; the average temperature of the whole column t' is assumed to be the average of the temperatures t_0 at the bottom and t_h at the top of the column. The weight of vapor in kilograms in the whole column of 1 square meter section is expressed by—

$$Q = \frac{0.0010582}{1+at'} p_0 \; 2830\left(1 - 10^{\frac{-h}{6517}}\right)$$

Tables in English measures based on the above formulæ

were prepared in 1884 for an unpublished fourth edition of the Signal Office circular "How to Use Weather Maps," and were also given in a condensed form on pages 409 and 410 of the Smithsonian Report for 1888; in response to several inquiries they are now reproduced herewith (see Table 1 for q and Table 2 for Q).

TABLE 1.—*Normal distribution of aqueous vapor for various altitudes above the earth's surface.*

Altitude in feet above sea level.	Relative tensions or weights by Hann's formula.	Actual weight in grains per cubic foot at any elevation for a given dew-point at the surface.			
		80°.	70°.	60°.	50°.
		Grains.	*Grains.*	*Grains.*	*Grains.*
0	1.000	10.95	7.99	5.76	4.09
2,000	0.806	8.83	6.44	4.64	3.30
4,000	0.650	7.11	5.19	3.74	2.66
6,000	0.524	5.75	4.19	3.02	2.14
8,000	0.423	4.63	3.38	2.44	1.73
10,000	0.341	3.73	2.72	1.96	1.39
12,000	0.275	3.01	2.20	1.58	1.12
14,000	0.221	2.42	1.77	1.27	0.90
16,000	0.179	1.96	1.43	1.03	0.73
18,000	0.144	1.58	1.15	0.83	0.59
20,000	0.116	1.27	0.93	0.67	0.47
22,000	0.094	1.03	0.75	0.54	0.38
24,000	0.075	0.82	0.62	0.43	0.31
26,000	0.061	0.67	0.49	0.35	0.25
28,000	0.049	0.54	0.39	0.28	0.20
30,000	0.040	0.43	0.32	0.23	0.16

The total quantity of vapor in the atmosphere may also be expressed by the depth it would occupy if all precipitated as rain, as in the following paragraphs (for precision the equivalent water is supposed to have the temperature of 39.2°, which is that of the standard maximum density of water):

For a vertical column of 1 square meter section, Q expressed in kilograms is equivalent to Q millimeters of rainfall at 39.2° for that same horizontal square meter.

For a vertical column of one square foot section, Q expressed in grains is equivalent to $\dfrac{Q}{36415.54}$ inches of rainfall at 39.2° for that same square foot.

This latter figure is based on the fact that 1 cubic foot of pure water at its maximum density, viz, for 39.2°, weighs *in vacuo* 62.42667 pounds avoirdupois of 7,000 grains each; at the temperature 62.5° the density of the water is less and the weight of a cubic foot is 62.355 pounds.

The total amount of moisture in a column of saturated air extending from sea level up to a given altitude is given in the following table by the depth in inches of the corresponding layer of water that would be formed if all the moisture were to fall to the earth as rain.

TABLE 2.—*Depth of layer of water in a column of air whose dew-point at the earth's surface is given.*

Height of column in feet.	80°.	70°.	60°.	50°.
	Inch.	Inch.	Inch.	Inch.
6,000	1.3	1.0	0.7	0.5
12,000	2.1	1.5	1.1	0.8
18,000	2.5	1.8	1.3	0.9
24,000	2.7	2.0	1.4	1.0
30,000	2.8	2.1	1.5	1.1

In order to use the preceding tables we need to know the current or the average dew-point at any given station. The normal values for a few stations were given in the publication above referred to, but the present Summary gives the average dew-point at 8 a. m. and 8 p. m. for the year 1894 at most of the Weather Bureau stations, and from these values the aqueous contents of the atmosphere can be computed, with the results, as shown in the following table.

TABLE 3.—*Total quantity of water contained in 30,000 feet of the lower atmosphere, expressed as depth of equivalent rainfall and corresponding to the mean local dew-point observed in 1894.*

No.	Station.	Inch.	No.	Station.	Inch.
	New England.			*South Atlantic States.*	
1	Eastport, Me	0.6	19	Charlotte, N. C	1.0
2	Portland, Me	0.7	20	Hatteras, N. C	1.4
3	Northfield, Vt	0.6	21	Kittyhawk, N. C	1.3
4	Boston, Mass	0.8	22	Raleigh, N. C	1.1
5	Nantucket, Mass	0.9	23	Wilmington, N. C	1.3
6	Woods Holl, Mass		24	Charleston, S. C	1.4
7	Block Island, R. I	0.9	25	Augusta, Ga	1.3
8	New Haven, Conn	0.9	26	Savannah, Ga	1.4
9	New London, Conn	0.9	27	Jacksonville, Fla	1.5
	Middle Atlantic States.			*Florida Peninsula.*	
10	Albany, N. Y	0.8	28	Jupiter, Fla	1.9
11	New York, N. Y	0.9	29	Key West, Fla	1.9
12	Harrisburg, Pa	0.9	30	Tampa, Fla	1.7
13	Philadelphia, Pa	0.9	31	Titusville, Fla	1.7
14	Atlantic City, N. J	1.0		*Eastern Gulf States.*	
15	Baltimore, Md	0.9	32	Atlanta, Ga	1.1
16	Washington, D. C	1.0	33	Pensacola, Fla	1.5
17	Lynchburg, Va	1.0	34	Mobile, Ala	1.5
18	Norfolk, Va	1.2	35	Montgomery, Ala	1.3

TABLE 3.—*Total quantity of water, etc.—Continued.*

No.	Station.	Inch.	No.	Station.	Inch.
	Eastern Gulf States—Cont'd.			*Missouri Valley.*	
36	Meridian, Miss	1.3	87	Columbia, Mo	
37	Vicksburg, Miss	1.2	88	Kansas City, Mo	0.8
38	New Orleans, La	1.5	89	Springfield, Mo	0.9
	Western Gulf States.		90	Omaha, Nebr	0.7
39	Shreveport, La	1.3	91	Valentine, Nebr	0.5
40	Fort Smith, Ark	1.1	92	Sioux City, Iowa	0.6
41	Little Rock, Ark	1.1	93	Pierre, S. Dak	0.5
42	Corpus Christi, Tex	1.3	94	Huron, S. Dak	0.5
43	Galveston, Tex	1.6		*Northern Slope.*	
44	Palestine, Tex	1.3	95	Havre, Mont	0.5
45	San Antonio, Tex	1.2	96	Miles City, Mont	0.5
	Ohio Valley and Tennessee.		97	Helena, Mont	0.4
46	Chattanooga, Tenn	1.0	98	Rapid City, S. Dak	0.5
47	Knoxville, Tenn	1.0	99	Cheyenne, Wyo	0.4
48	Memphis, Tenn	1.1	100	Lander, Wyo	0.4
49	Nashville, Tenn	1.0	101	North Platte, Nebr	0.5
50	Lexington, Ky	0.9		*Middle Slope.*	
51	Louisville, Ky	0.9	102	Denver, Colo	0.4
52	Indianapolis, Ind	0.8	103	Pueblo, Colo	0.4
53	Cincinnati, Ohio	0.9	104	Concordia, Kans	0.7
54	Columbus, Ohio	0.8	105	Dodge City, Kans	0.6
55	Pittsburg, Pa	0.9	106	Wichita, Kans	0.8
56	Parkersburg, W. Va	0.9	107	Oklahoma, Okla	0.9
	Lower Lake Region.			*Southern Slope.*	
57	Buffalo, N. Y	0.8	108	Abilene, Tex	0.9
58	Oswego N. Y	0.8	109	Amarillo, Tex	0.5
59	Rochester, N. Y	0.8		*Southern Plateau.*	
60	Erie, Pa	0.8	110	El Paso, Tex	0.4
61	Cleveland, Ohio	0.8	111	Santa Fe, N. Mex	0.3
62	Sandusky, Ohio	0.8	112	Tucson, Ariz	0.5
63	Toledo, Ohio	0.8	113	Yuma, Ariz	0.9
64	Detroit, Mich	0.8	114	Independence, Cal	
	Upper Lake Region.			*Middle Plateau.*	
65	Alpena, Mich	0.7	115	Carson City, Nev	0.4
66	Grand Haven, Mich	0.8	116	Winnemucca, Nev	0.3
67	Marquette, Mich	0.6	117	Salt Lake City, Utah	0.5
68	Port Huron, Mich	0.8		*Northern Plateau.*	
69	Sault Ste. Marie, Mich	0.6	118	Baker City, Oreg	0.5
70	Chicago, Ill	0.8	119	Idaho Falls, Idaho	0.4
71	Milwaukee, Wis	0.8	120	Spokane, Wash	0.5
72	Green Bay, Wis	0.7	121	Walla Walla, Wash	0.8
73	Duluth, Minn	0.5		*North Pacific Coast Region.*	
	North Dakota.		122	Fort Canby, Wash	0.9
74	Moorhead, Minn	0.5	123	Port Angeles, Wash	0.8
75	St. Vincent, Minn	0.5	124	Seattle, Wash	0.8
76	Bismarck, N. Dak	0.4	125	Tatoosh Island, Wash	0.8
77	Williston, N. Dak	0.4	126	Portland, Oreg	0.9
	Upper Mississippi Valley.		127	Roseburg, Oreg	0.9
78	St. Paul, Minn	0.5		*Middle Pacific Coast Region.*	
79	La Crosse, Wis	0.7	128	Eureka, Cal	0.9
80	Davenport, Iowa	0.8	129	Red Bluff, Cal	0.9
81	Des Moines, Iowa	0.7	130	Sacramento, Cal	0.9
82	Keokuk, Iowa	0.8	131	San Francisco, Cal	0.9
83	Cairo, Ill	1.0		*South Pacific Coast Region.*	
84	Springfield, Ill	0.8	132	Fresno, Cal	0.9
85	Hannibal, Mo	0.8	133	Los Angeles, Cal	1.0
86	St. Louis, Mo	0.9	134	San Diego, Cal	1.0
			135	San Luis Obispo, Cal	

The above figures refer to the ideal atmospheres above sea level, and must be diminished by the quantity that is supposed to lie between the station and sea level.

If this moisture were everywhere and entirely precipitated the weight of the atmosphere would be diminished, and the barometric readings would be lower than now by $\frac{1}{13.6}$ of the above figures, i. e., by the equivalent in mercury of the above given inches of water.